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Housing stability and diabetes among people living in New York city public housing

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Housing stability and diabetes among people living in New York city public housing

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ABSTRACT

Public housing provides affordable housing and, potentially, housing stability for low-income families. Housing stability may be associated with lower incidence or prevalence and better management of a range of health conditions through many mechanisms. We aimed to test the hypotheses that public housing residency is associated with both housing stability and reduced risk of diabetes incidence, and the relationship between public housing and diabetes risk varies by levels of housing stability. Using 2004-16 World Trade Center Health Registry data, we compared outcomes (housing stability measured by sequence analysis of addresses, self-reported diabetes diagnoses) between 730 New York City public housing residents without prevalent diabetes at baseline and 730 propensity score-matched non-public housing residents. Sequence analysis found 3 mobility patterns among all 1460 enrollees, including stable housing (65%), limited mobility (27%), and unstable housing patterns (8%). Public housing residency was associated with stable housing over 12 years. Diabetes risk was not associated with public housing residency; however, among those experiencing housing instability, a higher risk of diabetes was found among public housing versus non-public housing residents. Of those stably housed, the association remained insignificant. These findings provide important evidence for a health benefit of public housing via housing stability among people living in public housing.

1. Introduction

Housing stability – related to but conceptually distinct from housing quality and neighborhood effects – is an important social determinant of health. Having a safe, stable place to live and sleep can create a sense of control and consistency. This stability may help individuals manage their routines and reduce life disruptions, leading to better management of chronic disease conditions and improved health outcomes (Keene, Guo, & Murillo, 2018). In areas with limited affordable housing, achieving housing stability allows residents with low incomes to prioritize health and healthy behaviors as opposed to bearing the repeated cognitive, emotional, and financial burden of securing housing (Keene et al., 2018; Pfeiffer, 2018). Furthermore, housing stability creates opportunities for residents to build dense social networks that provide mutual support, knowledge, and aid that, in turn, promote health (Berkman, Glass, Brissette, & Seeman, 2000; Choi et al., 2017; de Vries, van Dillen, Groenewegen, & Spreeuwenberg, 2013; Duff et al., 2015; Erdem et al., 2015, 2016; Kawachi & Berkman, 2014). On an individual level, social networks – or the social ties that link people to each other – facilitate access to emotional, informational, instrumental, and appraisal social support as well as social engagement and attachment (Glanz, , Rimer, , & Viswanath, 2008). While driven by larger socioeconomic and political contexts, a particular behavior, knowledge, or resource may be shared and adopted among community members through social networks and a collective sense of community, and in turn make an impact on health (Villalonga-Olives & Kawachi, 2017).

Diabetes, like most diseases, is influenced by where and how we work, live, and play (Holtgrace and Crosby, 2008). The prevalence of

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diabetes among adults in New York City has been growing inequitably over the last decade, with Black, Latinx, and Asian residents experiencing almost three times the prevalence of White residents (Thorpe et al., 2018). While there are many evidence-based interventions to prevent and manage diabetes in the clinical setting, changing these troubling inequities at the population level requires investigating the role of structural drivers of diabetes incidence. An emerging literature suggests that housing stability may be one such driver. In a qualitative study of 40 adults with recent incarceration experiences, housing stability led to better diabetes management, including through the maintenance of specialized diets and medication adherence – key drivers of diabetes control (Keene et al., 2018). Recent research also finds associations between housing stability and decreased diabetes-related emergency department visits or hospitalizations among adults with diabetes (Berkowitz, Kalkhoran, Edwards, Essien, & Baggett, 2018). The relationship between housing stability and diabetes management has often focused on the provision of housing to people who are unstably housed as an intervention. Meanwhile, the relationship between housing stability and diabetes incidence is less explored. In one of the few studies focused on diabetes incidence, among Medicaid-eligible adults in New York City homeless shelters, housing placement as part of a supportive housing program was shown to decrease the risk of incident diabetes (Lim et al., 2019). However, housing stability and incident diabetes is seldom examined among people who are not in acute housing crisis.

Public housing can be conceptualized as an intervention for increasing housing stability in addition to its explicit mission of providing affordable housing for low- and moderate-income families (Stoloff, 2004). Public housing guarantees near-permanent tenure for its residents because public housing authorities do not impose time limits on occupancy, and federal regulations ensure that households pay no more than 30 percent of their income on rent (Bahchieva & Hosier, 2001; Dantzler & Rivera, 2018). In New York City, the average monthly rent for people living in public housing is $522, which is substantially lower than $3519, the average monthly rent for an apartment in New York City, (New York City Housing Authority, 2018; Rent Trend Data in New York, New York, 2019), and the average tenure is 22 years. People living in public housing develop strong ties to their community and are able to be emotionally attached to place, building cognitive social capital (Ehsan, Klaas, Bastianen, & Spini, 2019, p. 100425; Gibson, 2007; Manzo, 2014). They are also able to participate in community activities and form community groups thanks to physical settings of public housing, building structural social capital (Ehsan et al., 2019, p. 100425; Gibson, 2007).

Recently, beyond social benefits, researchers have systematically studied and reported a variety of health benefits among people living in public housing. Innovatively using matched data between National Health Interview Survey and Housing and Urban Development records, Simon, Fenelon, Helms, Lloyd, and Rossen (2017) identified individuals who were eligible for public housing and placed in the waitlist, and designated them as counterfactuals of people living in public housing. They then found that public housing residents were more likely to establish access to care compared with comparison group individuals. In addition, using the same data source and analytic approach, Fenelon et al. (2017) found evidence for health benefits of public housing residency as those living in public housing were less likely to report serious psychological distress and fair or poor health conditions.

In contrast, other research finds adverse health outcomes associated with public housing residence. For example, in a study of Boston residents, the authors described poor indoor housing quality in public housing as a probable explanation of higher asthma rates among those living in public housing compared with homeowners, as opposed to a more appropriate comparison group of Boston residents with low incomes navigating the poorly regulated private housing market (Mehta, Dooley, Kane, Reid, & Shah, 2018). In another Boston study, the authors reported elevated prevalence of being ever diagnosed with diabetes among people living in public housing versus people not living in public housing, although prevalence ratio was no longer statistically significant after controlling for race/ethnicity, income, and education (Digenis--Bury, Brooks, Chen, Ostrem, & Horsburgh, 2008). In a United States national study of adults aged 50 years or older, higher prevalence of fatigue and chronic diseases (e.g., diabetes, hypertension, stroke, etc.) was reported among those living in public housing, and the authors presented chronic diseases, stress, and social isolation due to neighborhood crimes as a potential contributing factor (Parsons, Mezuk, Ratliff, & Lapane, 2011). In addition, despite evidence of poorer health among individuals when they enter into public housing compared to the general population, researchers do not tend to take into account this underlying difference (Ruel, Oakley, Wilson, & Maddox, 2010). These studies may not adequately control for unobserved differences between public housing and non-public housing residents.

In this study, we sought to examine associations between public housing and health outcomes and the impact of housing stability on these outcomes. Unlike previous studies that considered public housing residency as a risk factor, we adopted the perspective of understanding a unique health-promoting asset associated with public housing residency. In particular, given that strong social assets via housing stability can help initiate and maintain preventive care and adopt health-promoting behaviors (e.g., better diet), we posited that health benefits of living in public housing could be manifested as a reduced diabetes risk (Gebreab et al., 2017; Vijayaraghavan, Jacobs, Seligman, & Fernandez, 2011). Because an average age of the study participants was 46 years old and many had baseline comorbid conditions, we believed that observing diabetes incidences over 12 years were plausible (Centers for Disease Control and Prevention, 2020). Thus, we aimed to test the following hypotheses that 1) public housing residency is positively associated with housing stability, 2) public housing residency is associated with reduced risk of diabetes, and 3) the association between public housing residency and risk of diabetes varies by housing stability (Fig. 1). We used data from a longitudinal cohort of individuals exposed to the 9/11 attacks to take advantage of its 12-year follow-up time to capture residential movement and observe development of chronic diseases.

2. Methods

2.1. Data sources

Data came from the World Trade Center (WTC) Health Registry, a longitudinal cohort study of 71,426 individuals exposed to the WTC terrorist attacks on September 11, 2001. Those eligible for the Registry included people who lived, worked, or went to school in lower Manhattan, passersby, and rescue/recovery workers and volunteers. The Registry conducts periodic surveys of all adult Registry enrollees. Recruitment into the cohort and the first survey (Wave 1) were conducted in 2003-4 to capture information about demographics, 9/11-related exposures, and physical and mental health conditions. Wave 1 participants were followed-up in 3 subsequent surveys over 12 years: Wave 2 (W2; 2006–2007), Wave 3 (W3; , 2010–2011), and Wave 4 (W4; 2015–2016). Detailed descriptions of WTC Health Registry recruitment and data collection are described elsewhere (Farfel et al., 2008). Along with the Registry survey, residential addresses of all adult Registry enrollees were recorded in 2004 and updated annually by the Registry staff. These annual address data in 2004–2016 were geocoded and used as a data source for housing stability.

2.2. Study population

The present analysis is based on a subset of adult Registry enrollees who lived in the New York City Housing Authority (NYCHA; public housing in New York City) at Wave 1 based on geo-coded address data, participated in both Wave 1 and Wave 2, and had no history of prevalent diabetes at Wave 1 (treatment group; n = 730). Additional selection criteria was having data on the first survey whether the person

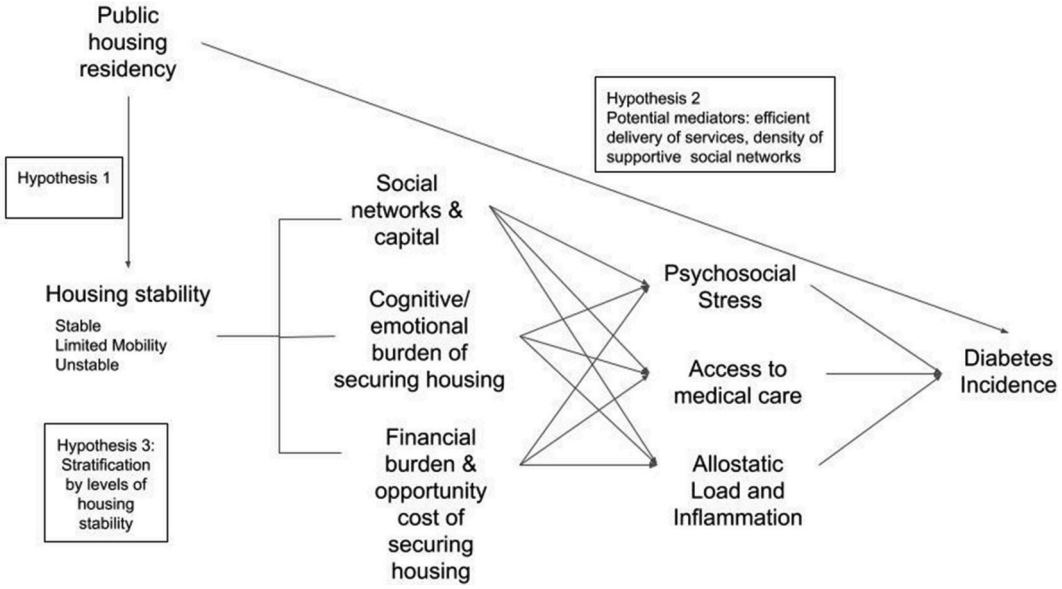

Fig. 1. Proposed key mechanisms linking public housing, housing stability, and diabetes incidence.

developed probable post-traumatic stress disorder (PTSD) or not according to the PTSD Checklist Civilian Version because PTSD at Wave 1 was a strong risk factor of mental and physical health among the Registry enrollees (Farfel et al., 2008). Those who moved into NYCHA during the follow-up period were not included in this study.

Because baseline characteristics differed between the Registry enrollees living in NYCHA ("treatment group") and those not living in NYCHA, we performed propensity score matching to identify 730 enrollees who were not living in NYCHA over 12 years and comparable to the treatment group members (see a more detailed description of propensity score matching in the statistical analysis section). The Registry enrollees in this comparison group met the inclusion criteria for the treatment group as described above except did not reside in NYCHA housing. The final sample size was 1460.

2.3. Variables

The main outcome of the study was housing stability, defined as a pattern of continuous residence (see a more detailed description of sequence analysis in the statistical analysis section). We used sequence analysis to summarize annual residential movement over 12 years using geo-coded address data of the study participants. Since there was no objective threshold to determine housing stability (e.g., defining housing stability by a particular number of residential movements), we decided to adopt this data-driven approach to measure housing stability. Previous studies demonstrated that sequence analysis produced a more valid housing stability measure compared with the one based on self-reports or counts of housing events (Lim, Singh, & Gwynn, 2017; McAllister, Lennon, & Kuang, 2011). Another outcome was self-reported diabetes. We ascertained diabetes cases if individuals without prevalent diabetes at Wave 1 answered "yes" to the survey question, "Have you ever been told by a doctor or other health professional that you had diabetes or sugar diabetes?" at any follow-up survey (e.g., Waves 2–4). The exposure variable was living in NYCHA at Wave 1. Lastly, covariates included Wave 1 demographic variables (income, education, sex, race/ethnicity, age, uniformed service members), Wave 1 PTSD, Wave 1 self-reported physical and mental health conditions (depression, heart disease, and hypertension), Wave 1 receipt of disability benefits prior to the 9/11 disaster, and Waves 2–4 survey participation status. To explore a potential role of cognitive and structural social capital in explaining an impact of public housing and housing stability on diabetes, we included Waves 3–4 PTSD, active participation in club/organizations in the past 30 days, and experiences of one of 6 stressful situations in the past 12 months (could not pay for food, housing, or other basic necessities; serious problems at work or lost a job; serious family problems involving your spouse, child, or parents; took care of a close family member or friend with a serious or life-threatening illness; serious legal problems; lost someone close to you due to accidental death, murder, or suicide). Since these data were only collected at Waves 3 and 4 and a large number of study samples did not respond to these questions mainly due to loss to follow-up (e.g., 32% at Wave 3, 42% at Wave 4), we only examined these as a post-hoc analysis and did not draw inference.

2.4. Statistical analyses

We first estimated the likelihood of having NYCHA residency (i.e., propensity score) via logistic regression using Wave 1 demographic characteristics (income, education, sex, race/ethnicity, age, uniformed service members), Wave 1 PTSD, and Waves 2–4 survey participation status, and identified survey participants not living in NYCHA who were comparable to those living in NYCHA via one-to-one nearest neighbor matching on propensity score (Table 1). Note that any variables about health conditions (e.g., hypertension, heart diseases) were not included as a covariate because these were more likely to act as a mediator of the association between NYCHA residency and diabetes rather than a common cause of NYCHA residency and diabetes (i.e., confounder). We then conducted sequence analysis to measure housing stability over the 12 years of follow-up, which allowed us to capture order and duration of housing events over time (Abbott & Tsay, 2000; McAllister et al., 2011). Using annual address data, we recorded a person's sequence of addresses across the 12 years as follows. The initial address in 2004 was marked as a 1. The first year a new address was recorded was marked as 2 until another new address was recorded. For example, if a person never moved during 12 years, we assigned a sequence of 1-1-1-1-1-1-1-1-1-1-1-1 to that person. If a person moved at year 3 and year 10, we assigned a sequence of 1-1-2-2-2-2-2-2-2-3-3-3 to that person. After creating these person-level sequences for all participants, we assessed the degree of dissimilarity among all possible sequence pairs of participants using the Levenshtein distance algorithm (Abbott & Tsay, 2000). We then performed a hierarchical cluster analysis with the Ward method and identified distinct clusters based on similar year-by-year residential movement. Lastly, we performed log-linear Poisson regression analysis using generalized estimating equations to test association between NYCHA residency and diabetes and effect modification on

Table 1
Selected baseline characteristics of the matched samples of the World Trade Center Health Registry enrollees, New York City, 2004–2016.

Baseline characteristics	NYCHA residents (n = 730)	Non-NYCHA residents (n = 730)	P-value
	Column %	Column %	
Household income in 2002			
<$10,000	14%	14%	0.86
$10,000- <$15,000	9%	10%	
$15,000 - <$25,000	14%	12%	
$25,000 - <$50,000	45%	46%	
$50,000 - <$75,000	11%	13%	
$75,000 - <$150,000	5%	5%	
$150,000+	1%	1%	
Education			
< high school degree	18%	19%	0.84
High school degree	35%	34%	
Some college +	46%	46%	
Average age in years (SD)	46 (13)	46 (13)	0.63
Uniformed service members	7%	6%	0.40
Sex: female	63%	66%	0.19
Race/ethnicity			
Non-Latino White	6%	6%	0.99
Non-Latino Black	38%	38%	
Latino	41%	41%	
Asian	11%	11%	
Others	4%	4%	
Physical and mental health conditions			
Heart disease	11%	8%	0.18
Hypertension	28%	22%	<0.01
Depression since the 9/11 disaster	62%	63%	0.76
Receipt of disability benefits before the 9/11 disaster	32%	29%	0.20

Notes: NYCHA = New York City Housing Authority (public housing in New York City); SD = Standard Deviation.

multiplicative scale via housing stability. We re-used covariates that were included in the propensity score model because this estimation approach was more effective in addressing bias due to model misspecification (Funk et al., 2011).

Statistical significance was determined using two-sided p value < 0.05. Propensity score matching was performed using *MatchIt* package, and sequence analysis was performed using *TraMineR* and *cluster* packages in R 2.14.2 software (R Foundation for Statistical Computing, Vienna, Austria). All other analyses were performed using SAS 9.4 software (SAS Institute, Inc., Cary, NC).

3. Results

Most people living in NYCHA (82%) reported household incomes less than $50,000 at Wave 1 and 54% obtained a high school degree or less (Table 1). Most were people of color (Non-Latino Black: 38%; Latino: 41%; Non-Latino Asian: 11%) with an average age of 46 years at Wave 1. Comparison group members had similar socio-demographic characteristics. Both groups were similar in terms of prevalence of heart diseases and depression at Wave 1, while higher hypertension prevalence was found among people living in NYCHA. In addition, there were no statistically significant difference in percent of people receiving disability benefits prior to the 9/11 disaster by public housing residency. Both treatment and comparison group members predominantly resided in lower Manhattan at Wave 1 (Appendix 1).

Based on the sequence analysis (Fig. 2), we identified 3 unique housing stability patterns in this population, including stable housing (n = 945, 65%), limited mobility (n = 395, 27%), and unstable housing (n = 120, 8%). Those with the stable housing pattern rarely moved, those with the limited mobility pattern moved 2 times on average, and those with the unstable housing pattern moved 4 times on average during the 12-year study period. Most people living in NYCHA (70%) and not living in NYCHA (60%) followed the stable housing pattern. After accounting for potential confounding, higher prevalence of housing stability among people living in NYCHA remained (prevalence ratio = 1.16, 95% CI = 1.07, 1.25).

NYCHA residency was not associated with reduced risk of new diabetes diagnosis (Table 2 and Fig. 3; relative risk (RR) = 1.11, 95% CI = 0.83, 1.48). However, we found that housing stability was a marginally significant effect modifier of the association between NYCHA residency and new diabetes diagnoses (p-value = 0.051). The association between NYCHA residency and new diabetes diagnosis was statistically significant among those with housing instability (RR = 1.59, 95% CI = 1.01, 2.50), indicating that the risk of new diabetes was higher among people who lived in NYCHA at Wave 1 but left vs. people who did not live in NYCHA and experienced housing instability. Of those with housing stability, the association remained insignificant (RR = 1.09, 95% CI = 0.71, 1.67).

According to the post-hoc analysis, individuals who moved out of NYCHA and experienced housing instability during the study period were more educated, younger, employed full-time at Wave 1, and had higher household incomes at Wave 1 compared with those who lived in NYCHA and had housing stability. Once moving out of the original NYCHA residence, they were unlikely to return to NYCHA; only 20% had records of NYCHA addresses over 12 years. However, these individuals reported higher prevalence of PTSD and life stress and lower prevalence of active participation in club/organizations in the past 30 days at Wave 3 and Wave 4 compared with people living in NYCHA with housing stability as well as people not living in NYCHA (Appendix II).

4. Discussion

We found that public housing residency was associated with housing stability over 12 years among adults affected by the 9/11 attacks. We did not find reduced diabetes risk among people living in public housing, but of those who experienced housing instability, higher risk of diabetes was observed among people living in public housing versus people not living in public housing.

Unlike previous studies (Digenis-Bury et al., 2008; Parsons et al., 2011), public housing residency was not associated with an elevated risk of diabetes. This difference might be attributable to how the comparisons group was selected. In our study, people not living in public housing who were comparable to people living in public housing were identified via propensity score matching. In other studies, while only a small number of variables about baseline characteristics were included, comparability between treatment and comparison groups (e.g., people not living in public housing, home owners, or general population) were not thoroughly evaluated (Digenis-Bury et al., 2008; Parsons et al., 2011). The other possible explanation is that previous studies used data collected at a single point in time. Because of the lack of temporality when using cross-sectional data, cross-sectional studies examining the association between public housing and diabetes are more susceptible to bias due to confounding (Oakes, 2004). Given poor chronic health conditions reported at entry to public housing (Ruel et al., 2010), it is important to select individuals without prevalent diabetes at baseline in order to test a pathway from public housing residency to diabetes.

People living in public housing were more likely than people not living in public housing to remain stably housed over this 12-year period. This finding is consistent with a recent study where people receiving housing assistance in Southeastern Michigan were more likely to experience subsequent housing stability after the 2008 financial crisis, as opposed to those who had similar incomes, but did not receive housing assistance (Kim, Burgard, & Seefeldt, 2017). Several potential factors might explain the long occupancy tenure of people living in public housing. One such factor is affordability of public housing rent despite the increasing trend of rental prices in New York City (McClure, 2018). Other factors could be structural social capital, including on-site community centers and social services in some developments and the

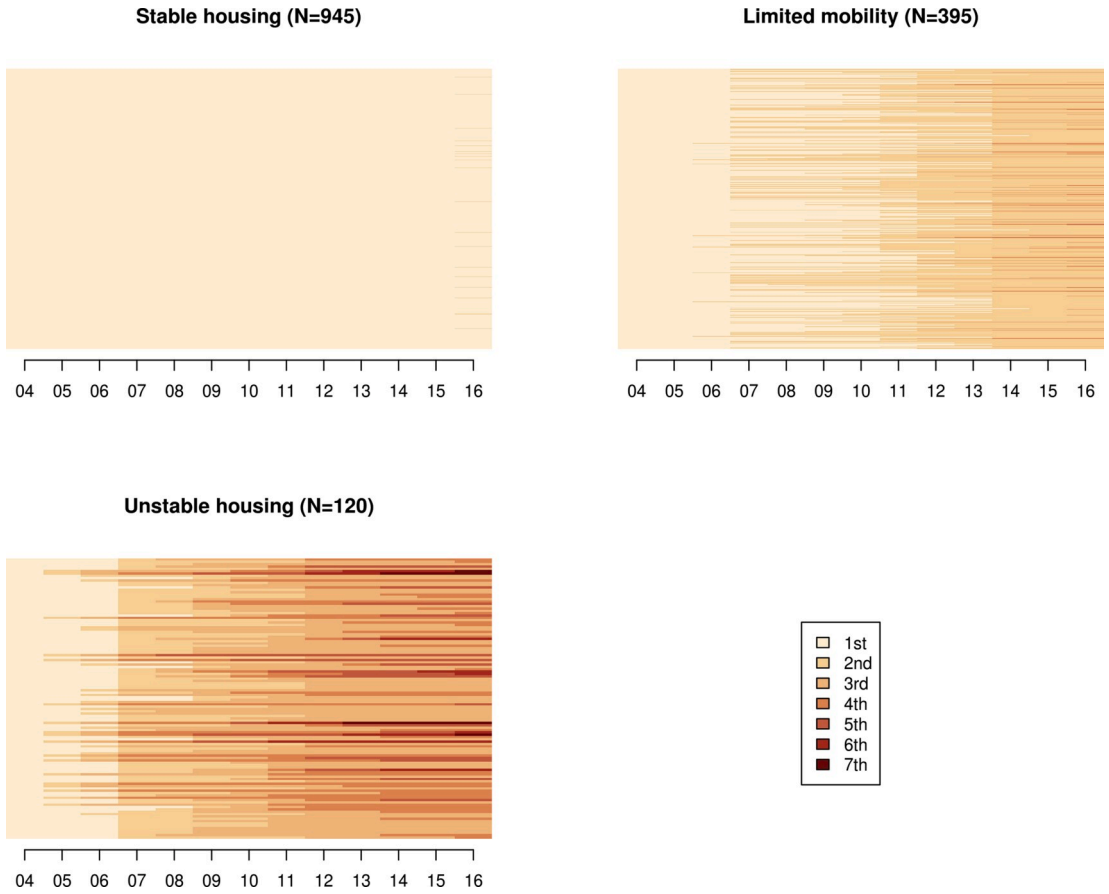

Fig. 2. Housing stability patterns among the matched samples of the World Trade Center Health Registry enrollees, New York City, 2004–2016
Figure captions: each horizontal line in the y-axis represents an individual-level sequence of annual records of residence during 12 years. The x-axis represents each year of 12 years. Change in darker color indicates residential movement. For example, if a very light red color (labelled as 1st in the legend) is switched to a slightly darker color (labelled as 2nd in the legend), it represents an individual who has moved from the original residence in 2014 to a new residence. These sequences are stacked together and divided into three distinct clusters based on their similarities. The height of the original plot is proportional to the number of individuals in each cluster, but then adjusted to the same size to more clearly show color patterns. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Relative risk for new diabetes diagnosis by public housing residency among the World Trade Center Health Registry enrollees, New York City, 2004–2016.

	RR (95% CI)*
All	
Non-NYCHA residents	Reference
NYCHA residents	1.11 (0.83, 1.48)
Individuals without housing stability	
Non-NYCHA residents	Reference
NYCHA residents	1.59 (1.01, 2.50)
Individuals with housing stability	
Non-NYCHA residents	Reference
NYCHA residents	0.90 (0.62, 1.30)

Notes: CI = confidence interval; NYCHA = New York City Housing Authority (public housing in New York City); RR = relative risk.
*Wave 1 demographic variables (income, education, sex, race/ethnicity, age, uniformed service members), Wave 1 PTSD, and Waves 2–4 survey participation status, which were predictors of propensity score, were re-used as covariates of the log-linear Poisson regression models.

support for tenant organizing and leadership. Besides providing relatively low-cost rent in an increasingly expensive city, several NYCHA housing developments actively provides opportunities for residents to establish or strengthen social ties. For example, among NYCHA's 325 developments, there are 121 senior centers, which represent almost half of all the senior centers in New York City (Gates et al., 2018). As demonstrated in this study, once people living in public housing are moving out and these health-promoting factors are not available, risk of developing diabetes may increase. Our post-hoc analysis indicates that these individuals were less likely to actively participate in club/organizations in the past 12 months compared with people staying in NYCHA or not living in NYCHA. Further studies with more complete social capital data are warranted to test a role of structural social capital in an impact of housing stability on diabetes among people living in public housing.

Of the subgroup who experienced housing instability, a higher risk of self-reported diabetes was found among people living in public housing vs. people not living in public housing. One possible mechanism for this finding is a pathway from relocation to stress, which is then linked to diabetes. Evidence shows that being relocated from public housing after public housing demolition can substantially disrupt social cohesion and social support (Clampet-Lundquist, 2010; Kleit & Manzo, 2006). As explained by Berkman and colleagues' social integration and health framework (2000), relocation can decrease cognitive social capital via the disruption of social network, reducing an individual's capacity to deal with life stressors (Grant, Hamer, & Steptoe, 2009). Our post-hoc analysis found a higher prevalence of PTSD and lifetime stress among people living in public housing with housing instability compared with those not living in public housing with housing instability. Similar to stress, previous studies found that PTSD or depression was a significant

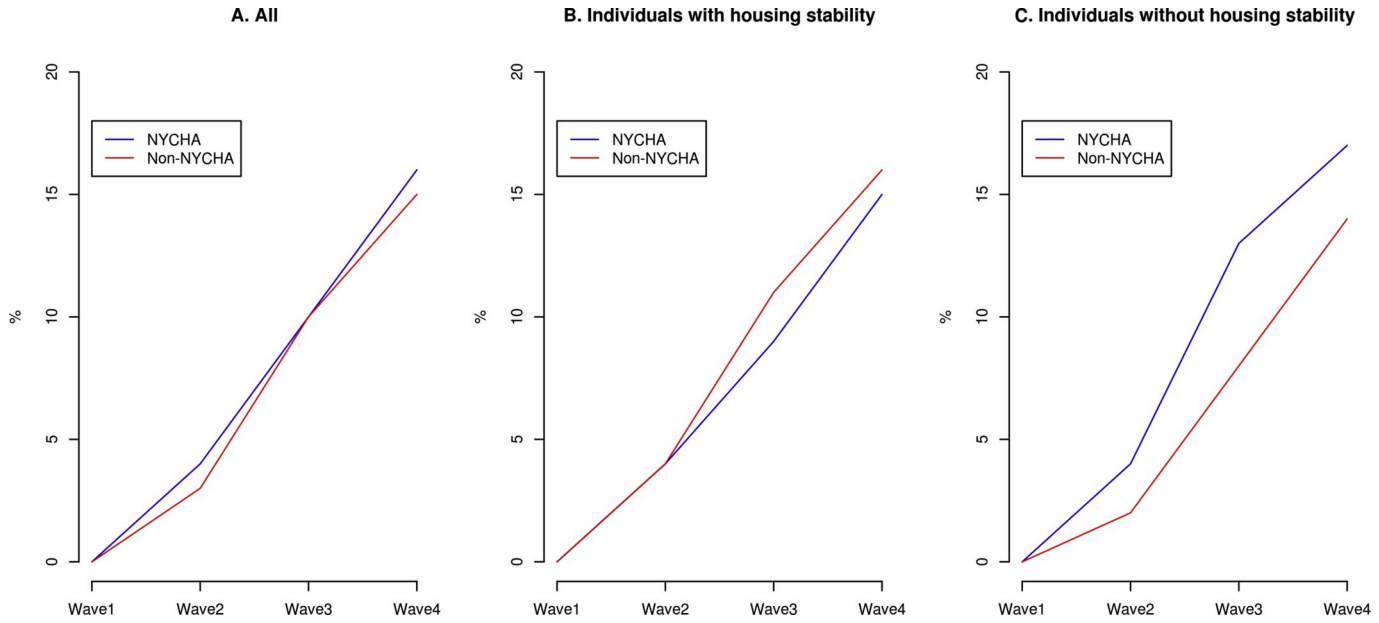

Fig. 3. Predicted risk of new diabetes diagnosis* by public housing residency among the World Trade Center Health Registry enrollees, New York City, 2004–2016
Figure captions: *Wave 1 demographic variables (income, education, sex, race/ethnicity, age, uniformed service members), Wave 1 PTSD, and Waves 2–4 survey participation status, which were predictors of propensity score, were re-used as covariates of the log-linear Poisson regression models. Each line represents a risk of new diabetes diagnosis over time by public housing residency for all as well as housing stability groups, predicted by the regression models.

risk factor for diabetes (Gebreab et al., 2017; Miller-Archie et al., 2014; Nichols & Moler, 2011).

Researchers have proposed clinical explanations for the observed association between stress and diabetes. One hypothesis is that a large amount of particular hormones such as cortisol are released when body systems continue to be over-activated over time due to continued exposure to stressful circumstances, elevating a blood glucose level and developing insulin resistance (Golden, 2007; Joseph & Golden, 2017). Another explanation is that stress stimulates production of proinflammatory cytokines. Persistent inflammation negatively affects immune and endocrine systems, resulting in development of diabetes (Champaneri, Wand, Malhotra, Casagrande, & Golden, 2010).

Several limitations should be noted in this study. First, the generalizability of the study findings may be limited because our study sample was drawn from those who were affected by the 9/11 terrorist attacks and participated in at least both Wave 1 and Wave 2 surveys. Second, diabetes diagnoses were based on self-report, and therefore do not include those who may be undiagnosed. Without information about undiagnosed diabetes the reported association between public housing and risk of diabetes might have been biased toward the null because people living in public housing, as opposed to those not living in public housing, were more likely to maintain healthcare access and get diagnosed with diabetes (Simon et al., 2017). However, since the associations among public housing, healthcare access, and diabetes could operate through multiple mechanisms, it is hard to ascertain a direction of bias without critical information (e.g., receipt of preventive cares, medications). Third, the Registry did not collect information on reasons for moving. Although the decision to move out of NYCHA appears voluntary given that those who moved out were predominately younger, more educated, and of higher income than those who stayed, we cannot completely rule out eviction, a hugely stressful event, as a reason for moving. Fourth, bias due to unobserved confounding cannot be ruled out although any observed differences were rigorously evaluated and accounted for. Lastly, we did not characterize a type of neighborhoods where former NYCHA residents were settled after leaving NYCHA or characteristics about neighborhood change that occurred around NYCHA buildings.

Recent studies show improved health outcomes among former public housing residents who moved to high socioeconomic status neighborhoods; our findings might mask potentially positive impacts of moving (Cooper et al., 2013, 2014). Further, many neighborhoods where NYCHA sites are located have experienced substantial racial/ethnic, socioeconomic, and other change (i.e., gentrification) during this same period; the resulting displacement of the residents surrounding public housing buildings may have disrupted social networks during the study period (Lim et al., 2017). However, this study does not directly evaluate social networks of NYCHA residents, which is methodologically intensive, costly, and infeasible. Future studies with a larger sample size are warranted to examine differential health impacts of moving from public housing. Despite these limitations, a main strength of this study was use of 12-year address data, which provided more accurate information about residential movement than self-reported data. Using sequence analysis, we captured of the number of residential movements into the housing stability measure. In addition, longitudinal data allowed us to establish temporality between exposure and outcome. Lastly, propensity score matching addressed underlying differences between people living in NYCHA and people not living in NYCHA and strengthened the internal validity of these findings.

5. Conclusion

Living in public housing was associated with housing stability over 12 years among New York City adults affected by the 9/11 attacks. Public housing residency was neither associated with decreased nor increased risk of diabetes. Yet, for the subgroup of unstably housed adults, those living in public housing had a persistently higher prevalence of PTSD and life stress than those not living in public housing, and higher risk of diabetes. We believe that control and consistency in daily life and social capital via housing stability potentially helps mitigate risk of developing diabetes among public housing residents despite individual and environmental challenges. On the other hand, moving out of public housing may cause residents to be disconnected to social capital, and corresponding health benefits, triggering a health-damaging mechanism. This study provides important evidence that promoting and supporting housing stability among people living in public housing should be considered as a public health priority for low-income urban

residents.

Human participant protection

The Institutional Review Boards of the Centers for Disease Control and Prevention and New York City Department of Health and Mental Hygiene approved the study protocol.

Author declaration

S Lim, E Hamby, and S Farquhar conceived the study and led the writing of the article and statistical analyses. S Locke, M Jacobson, E Poirot, and A Crossa performed data managements and geocoded address data. S Liu, M Jacobson, J Brite, S Farquhar, and Z Bailey assisted with the interpretation of data and policy implications. All authors contributed to the review and editing of drafts of the article and approved the version to be published.

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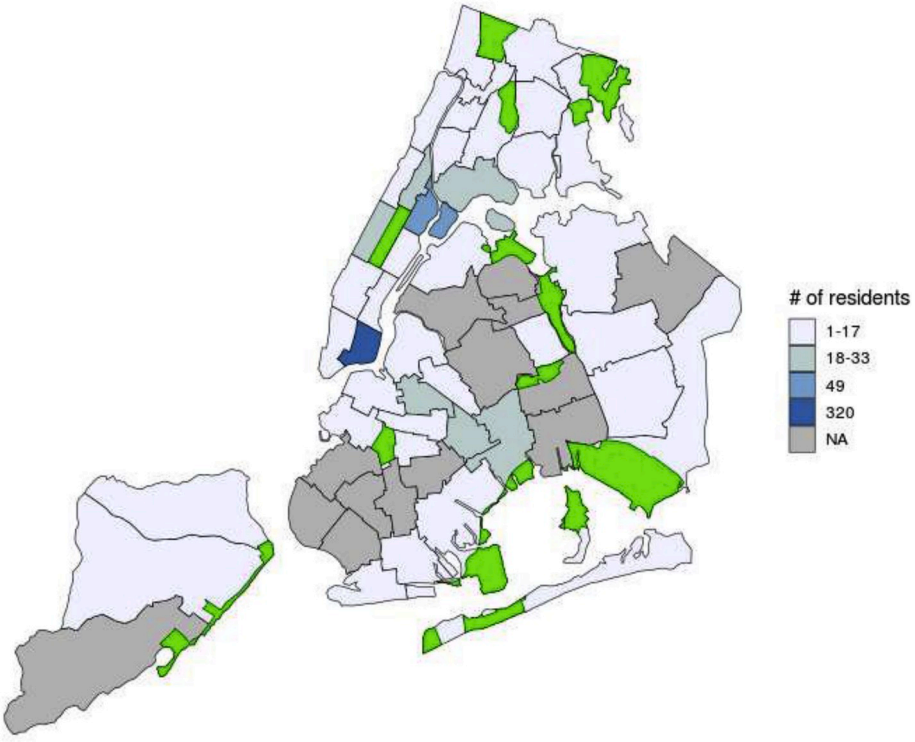
Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100605.

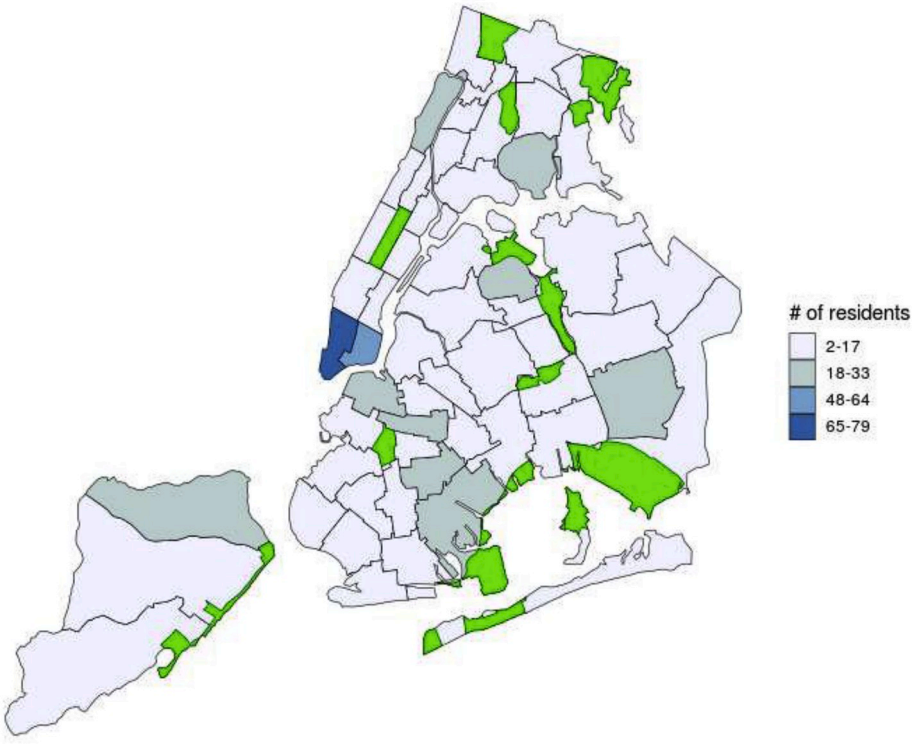
Appendix 1. Spatial distributions of the matched samples among the World Trade Center Health Registry enrollees, New York City, 2004–2016

A. NYCHA residents.



Notes: green color represents unpopulated areas.

B. Non-NYCHA residents.



Notes: green color represents unpopulated areas.

Appendix 2. PTSD, active participation in club/organizations in the past 30 days, and life tress at Waves 3 and 4 by public housing and housing stability

	NYCHA residents		Non-NYCHA residents		NYCHA residents				Non-NYCHA residents			
					Housing stability		Housing instability		Housing stability		Housing instability	
	N[a]	%[b]	N[a]	%[b]	N[a]	%[b]	N[a]	%[b]	N[a]	%[b]	N[a]	%[b]
PTSD at Wave 3	451	28%	460	28%	313	26%	138	33%	285	29%	175	27%
PTSD at Wave 4	383	22%	388	23%	246	19%	137	28%	225	24%	163	21%
Active participation in club/organizations in the past 30 days at Wave 3	490	19%	497	24%	345	19%	145	20%	314	27%	183	18%
Active participation in club/organizations in the past 30 days at Wave 4	417	18%	430	27%	275	19%	142	16%	251	27%	179	26%
Life stress at Wave 3[c]	494	9%	500	7%	347	8%	147	11%	313	8%	187	6%
Life stress at Wave 4[c]	433	8%	454	6%	283	7%	150	11%	269	6%	185	6%

[a]denominator.
[b]% of individuals with outcomes.
[c]3+ out of 6 stressful events in the past 12 months (could not pay for food, housing, or other basic necessities; serious problems at work or lost a job; serious family problems involving your spouse, child, or parents; took care of a close family member or friend with a serious or life-threatening illness; serious legal problems; lost someone close to you due to accidental death, murder, or suicide).

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